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East Europe Report

SCIENTIFIC AFFAIRS

No. 692

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SOCIALIST COOPERATION IN MICROELECTRONICS DISCUSSED

Budapest HIRADASTECHNIKA in Hungarian Vol 31 No 9, 1980 pp 334-336

[Article by Jan Grzybowski and Jerzy Kucinski, Poland, SEP (Association of Polish Electrical Engineers)]

[Text] Aircraft manufacture and space research are among the most miraculous achievements of postwar developments. However, the growth of the electronics industry is of similar importance; as a matter of fact, its effects are felt practically everywhere and contribute to advancement in almost all sectors of human activity.

Today we find no area of life in an industrially developed society where electronics is not involved; the degree of saturation with electronics is rightfully regarded as a measure of the development of the economy.

In spite of a high degree of saturation with new technological processes, the electronics industry never ceases to grow. Without this growth, electronics cannot develop further. This applies particularly to microelectronics, which today is a symbol of the sophistication and degree of development of the electronics industry. An increasing percentage of the cost of electronic devices (presently 8 percent, and estimated to become 10 percent by 1985) involves solid-state devices, in spite of the fact that these devices become cheaper as time goes on.

Making major simplifications, we might say that the manufacture of solid-state devices is the function of five basic factors:

- Degree of training of personnel (qualifications)
- Levels of manufacturing technology and their basic conditions
- Supply of raw and other materials

- Availability of technological measuring devices
- Level of demand for the products.

The nature and extent of the availability of these five conditions differs in the various CEMA countries, thus making the degree of development of their solid-state manufacturing industries different. It may be stated that no CEMA country, except the Soviet Union, is capable of becoming a leader in microelectronics from its own resources alone. Nonetheless, the CEMA countries have serious work ahead of them, and they conduct a dynamic manufacturing and development activity in the field of solid-state devices.

The following are the basic difficulties of further development: problems related to the implementation of new manufacturing technologies, and the lacking base for the production of technological and measuring equipment, especially insofar as these concern the manufacture of LSI's. In these areas, it seems, a high level of development can be achieved only if we make joint use of the maximum accomplishments of the individual countries. These are not just high-faluting words; they express a need: more dynamic growth of the economies can only be achieved if this is observed.

Let us note that work has already started on the technological integration of the technologies of the individual countries, although by far not to the degree that would be desirable. We can cite three examples illustrating the successful cooperation among CEMA countries in the field of microelectronics:

- Cooperation between the GDR (RFT [Radio and Communications Technology]) and Czechoslovakia (Tesla) in the area of technological equipment;

- Division of the work between Poland (Unitra-Wemi) and Czechoslovakia (Tesla) in the field of development and manufacture of digital integrated TTL circuits;

- Division of the work between the Soviet Union and Poland in the development of the following products: low-power digital integrated TTL circuits, microprocessor circuits, and technological equipment for the manufacture of integrated circuits.

A CEMA decision was promulgated a few years ago concerning the introduction of a unified digital system and the development of a minicomputer system. The results of this collaboration are well-known today: we now have digital devices in the -2 series; preparation of digital devices in the -3 series is underway; and the development of the next-generation equipment of the unified system is in progress. This cooperation would be impossible for the creation of equipment without cooperation in the area of the components at the required level. A separate working group is engaged in the study of the problems related to this. Although it has been existence only for a short time, it has already accomplished much, for example it has developed the methodology of the development of the component base of digital technology, compiled the information concerning the new structure of informatics about the proposed list of components proposed for application, established recommendations for the development of new solid-state devices, and prepared many items of documentation concerning methodology, organization, and standardization.

It is desirable to establish a similar working group within the framework of the REP [expansion unknown] Permanent Committee. The task of this group would be the charting of the IC technologies developed in all CEMA countries, as well as the charting of the potential available in terms of technological facilities of the solid-state industry and measuring instruments. In our judgment, the present status in microelectronics in the CEMA countries represents a realistic base for the joint development of a number of products (such as microprocessor circuits, LSI-MOS circuits, circuits with Schottky diodes, TTL series, low-power TTL series, and others).

Some microprocessor systems are already under development in certain CEMA countries (some are already actually available). It would be desirable if these countries would specialize on the development of these systems with the goal of meeting the needs of all CEMA countries for them. But is is also necessary to develop new, highly complex LSI circuits and systems, making use of the technological potential and joint development. Among the MOS-LSI circuits, the most frequently used ones are microprocessor circuits, and also memory circuits, calculator circuits, and clock circuits.

Cooperation is possible in this area too (so that the needs of the other socialist countries can be met by the specialization of some).

The rapid growth of microelectronics, on which—in a broader sense—the electronization of the economies of our countries is based, makes it necessary to include in this program not only the cadres working in the electronics industry (engineers and technicians) but also those who utilize modern electronics in the various sectors of the economy. They must all contribute intensively. The scientific and technical associations of the socialist countries have a particularly important role to play here.

These associations must determine the strategy and the conditions of microelectronics development on the basis of specialized knowledge and institutional objectivism. Certain methods of social work to be performed in this area have already been discussed at the previous conference, which was held in Dresden. The forms of scientific and technological cooperation among the associations were also discussed there. Unfortunately, the program prepared at the conference in Dresden, which would have meant the implementation of the decisions reached, was not translated into actual practice. We have no full information concerning the activities of the individual scientific and technological associations; however, there are several signs to the effect that the work has started only in a few associations, and even there it is not continuous or comprehensive.

The Popov Institute in the Soviet Union has chosen as its primary activity the sponsoring of scientific and technological conferences, symposia, and seminars, as well as factory visits. The goal of these events is the exchange of information and the opportunity for consultations on problems encountered in the individual countries. Mention should be made of the annual lecture series on "Days of the Radio," in which problems associated with microelectronics often play a leading role. Participation of specialists representing the socialist camp has been considerable at the "Days of the Radio" conferences for some years. This refers particularly to members of the associations in the GDR, Poland, and Hungary; only one or two participants represent the other associations. Insofar as subject matter is concerned, the most interesting ones are the use of opto-electronic devices and measurement/control equipment (and systems). The Microelectronics and Solid-State Devices Section of the Popov society is particularly active; for example, it has sponsored a regional conference in the Uzbekian Soviet Socialist Republic on the subject of the use of microelectronics in agriculture and the light industries. According to the leadership of the Popov society, the level of the application of microelectronic technology in the economy is not yet satisfactory; thus, the Tenth Five-Year Plan stresses the goals concerning the development of this technology. In connection with this, the Popov society will stress in the near future the use of microelectronics in cosmic communications, the widening use of microprocessors, the use of microelectronics and optoelectronics in control engineering, and environmental protection. Special recognition is due to the strengthening of the relationship between the scientific and technological associations of the Soviet Union and GDR, as a result of which, for example, bilateral conferences and seminars are sponsored on problems of microelectronics.

Electrical engineers joined in the Chamber of Technology have formed an electronics section, where considerable attention is given to microelectronics as the basis of the growth of other industries and of energy savings. Special microelectronics consultation centers have been set up in ten major cities of the GDR. The first conference on microelectronics in the socialist countries was held in Dresden, in 1978. Unfortunately, only a few colleagues from the GDR participated in the second conference, which was held in Torun. This contrasts with the fact that approximately 300 delegates attended the Dresden conference from the host country (Poland).

For all practical purposes, the Association of Czechoslovak Electrican Engineers (CSVTS) did not participate actively at the present conference in Torun, nor did send information about their activities and achievements in the field of microelectronics. All we know is that there will be an international microelectronics conference this fall in Czechoslovakia. In our opinion, it is important to stress that it was in Prague where the scientific and technological associations of the socialist countries approved the resolution dealing with the sponsorship of joint conferences, of which the first was held in Dresden and the second one is presently held in Torun.

Activities related to microelectronics at the Energetics, Electrical Engineering, and Communications Technology Association of Bulgaria (HTC) are in its electronics section. In addition to sponsoring scientific and technological conferences, the HTC sponsors courses on the application of microelectronics, and also prepares training aids. Approximately 300 experts have participated in these courses during the last two years. This association has also developed the plan of cooperation with similar associations in the GDR.

The Scientific Association of Communication Engineering in Hungary participates intensively in subjects related to microelectronics both within the borders of the country and beyond. The HTE has sponsored an international conference on the use of microprocessors in the economy and on the possibilities of extending such use. At the request of the KGM [Ministry of Metallurgy and Machine Manufacture], the HTE has evaluated the long-range development plans for the electronics industry of Hungary. The HTE was an active participant at the first microelectronics conference held in Dresden, has cooperated closely with the Association of Polish Electrical Engineers (SEP) in the preparation of the second conference, and is represented with the largest group among the participants of the "Microelectronics '80" conference presently held in Torun.

A microelectronics section was established within the electronics department of the SEP. This section works intensively within its field and develops its activities further. It has prepared and sponsored numerous conferences dealing with the science and technology of microelectronics (for example: broadening the use of integrated circuits to promote the electronization of the economy, computer-asisted designing of integrated circuits, and so forth). The second "Microelectronics '80" conference of the socialist countries is presently in progress. The Tenth European Microwave Conference and the Fourth European Circuit-Theory and Designing conference will be held this September in Warsaw. It should be noted in this connection that this is the first time one of these conferences is held in a socialist country.

The SEP has developed and submitted to the relevant authorities several projects, all of which are important for the economy. They include:

- Proposals for the development of the solid-state industry;
- Proposals concerning the complex development plan of the electronics industry;
- Report-like document for the Eight Congress Committe of the Party on the status and development prospects of the electronic-component industry.

It can be seen that these projects submitted to the relevant authorities affected significantly the final decisions in the matters concerned, as it was expected by the activists within the SEP.

To celebrate the 60th anniversary of the establishment of the SEP, an exhibition with the slogan "Electricity - Economy - Society" was held in June 1979. This event, which was praised in political and economic circles, featured microelectronics.

Within the framework of the celebrations of the 60th anniversary of the establishment of the SEP, the editors-in-chief of the electronics journals of the socialist countries have met in Warsaw. At this meeting, the guidelines and extent of cooperation and information exchange were decided upon. According to the decisions, the journals will play an important role in the development of microelectronics by informing their readers on achievements in this field. For example, the second issue of the year 1970 of the Polish journal ELEKTRONIKA has been devoted to the "Microelectronics '78" conference held in Dresden, of which it published detailed reports. The issue of ELEKTRONIKA to cover the "Microelectronics '80" conference is also expected to be similarly detailed.

The SEP has sponsored numerous lectures and symposia, both domestically and abroad, dealing with microelectronics. It has also set up correspondence courses in electronic subjects, all stressing problems of microelectronics. This activity intensified to such a degree that an Electronization Consulting Bureau and a Committee on Matters Related to the Electronization of the Economy were ultimately established. These two institutions study primarily microelectronics and its applications in the economy.

Activists of the SEP and specialists delivered several lectures in Berlin on the use of microelectronics in consumer devices and motorized technology.

If we review the two years which have passed since the "Microelectronics '78" conference we find that although the scientific and technological associations of the socialist countries have sort of fulfilled their programs concerning the spreading of microelectronics in their respective economies, they have accomplished only modest progress in the field of cooperation. The associations have not performed the tasks they accepted at the microelectronics conference held in Dresden, concerning specialization of manufacture, cooperation, and evaluation of joint plans.

The number of socialist delegations attending the present conference (in Torun) characterizes the extent and intensity of the cooperation.

To deepen the cooperation which is needed in the field of microelectronics, we believe that one or two so-called round-table conferences each year would be useful. Only one or two participants from each socialist country should attend these. The subject matters would involve discussion and evaluation of selected subjects, and the formulation of recommendations or proposals for CEMA organs and countries.

We are sure that bilateral socialist cooperations would also very useful. We expect the understanding of our partners and their help in all steps we undertake toward the development of the microelectronics industry, as well as in all our activities aimed at developing our economies more intensively.

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CSO: 2502

ACTIVITIES AT NUCLEAR RESEARCH INSTITUTE IN REZ

Prague VYBER INFORMACI Z ORGANIZACNI A VYPOCETNI TECHNIKY in Czech May 80 pp 672-674

[Article by K.S.: "On the 25th Anniversary of the Existence of the Nuclear Research Institute at Rez Near Prague"]

[Text] The industrial development of nuclear energy and technology is characterized at the present time in the CSSR--as it is in the rest of the world--by the rapid pace of innovation, the successful implementation of which demands that the necessary attention be devoted to the development of a research and developmental base. The Nuclear Research Institute (UJV) in Rez, near Prague, is the largest research and development facility in the CSSR focusing on the peaceful utilization of nuclear energy. This past June it celebrated the 25th year of its existence. While in the past it has successfully conducted basic research in nuclear fields, at the present time it is successfully fulfilling tasks of an engineering nature with concrete, implementable results, through which it is actively taking part in the development of the Czechoslovak nuclear energy program and in the practical utilization of ionizing radiation.

The January 1955 decision of the Soviet Government to provide us, and other socialist countries as well, with wide ranging assistance in the establishment of an appropriate research base had a fundamental significance for the CSSR in the utilization of nuclear energy for peaceful purposes. Thus, by a decision of our government, the Institute of Nuclear Physics was created on 10 June 1955. It was renamed shortly thereafter the Nuclear Research Institute and incorporated into the Czechoslovak Academy of Sciences. The original incorporation of the UJV into the Czechoslovak Academy of Sciences determined the predominate focus of its activity on basic research, and its mission was to develop basic and applied research in nuclear fields and to educate specialists. In addition, it has also successfully contributed to several industrial applications of nuclear specialties, for instance in the production of cryogenic equipment and of selected radioactive pharmaceuticals, etc. It also participated in the construction of the first Czechoslovak nuclear power plant, particularly in the area of reactor physics and related areas. The gradual development of nuclear energy in the CSSR also urgently required the thorough and committed restructuring of the research and development program of the institute so that it is fully subordinated to the needs of the state plan. Therefore, a government decision divided the UJV of the Czechoslovak Academy of Sciences into three organizations:

The Nuclear Research Institute
The Institute of Nuclear Physics
The Laboratory of Radiological Dosimetry

The Nuclear Research Institute at Rez, near Prague, has been subordinated, since 1 January 1972, to the Czechoslovak Atomic Energy Commission, while the other two institutes have remained parts of the Czechoslovak Academy of Sciences. The principal content of their work, according to the new statute, is research in the area of atomic energy, which may be divided into two basic thematic fields: in the first place, in terms of extent and the importance of the results in applied research in nuclear energy, which at the present time is focused primarily on problems of the VVER type light water reactors, although problems concerning promising fast reactors are also being addressed. Although the tasks in the area of nuclear energy are of a long range character, the UJV is approaching them in such a way as to make immediate contributions to the national economy, and in such a way that the findings can be used in nonnuclear sectors as well. For instance, the completed, implementable result of the state task, "Fast Reactor Development in the CSSR" made possible the production and delivery to the USSR of a second steam generator of world class quality for the BOR-60 reactor, and provided a profit of Kcs 20 million for the producer.

Certification tests of the pressure vessel material of the VVER reactor, also conducted at UJV, made possible the beginning of the production and export of pressure vessels, at the same time that production costs savings amounted to 2 million foreign exchange korunas. The final utilization of the findings of nuclear flouride technology for the regeneration of rare metals and the production of synthetic diamonds represents an innovation of great importance in nonnuclear industry which contributed Kcs 8 million in 1979.

The second area which concerns the institute is research in ionizing radiation, including research and development of radiation technologies, radionuclidic preparations for medicinal and biological applications, neutron activation analysis, and semi-conductor detectors. In connection with these projects the institute also produces and supplies germanium semiconductor detectors and radioactive pharmaceuticals for the needs of the national economy and for export. The economic effects of these products are definitely not negligible, given that in this past year alone yields from these activities (detectors and cryogenic technology) represented Kcs 46 million, including foreign currency, while radioactive pharmaceuticals for improving diagnostic techniques in the health care system yielded Kcs 660 million. A part of the UJV capacity is utilized for work of a service character which could not be conducted without the use of several unique pieces of institute equipment such as the reactor, hot cells, and the like. In addition to these basic functions, institute activity includes other fields of work and specialized services, one of which is digital computing technology.

Having been built in a centralized way in the interest of fulfilling research and development projects, the facility also assures consultational activity during programming, organizes instruction in the area of programming languages, develops new programs, maintains a library of standard programs, and assures the economical operation of computers, their maintenance and systematic modernization. Since 1965, the institute has had at its disposal a GIER-4 computer of Danish manufacture which has performed extraordinarily well and puts out 7,400 operational hours per year. The reasons that this computer is still in operation may be found in its reliability, ease of maintenance, and especially in its excellent software outfitting. The ALGOL programming language is used almost exclusively, and its compiler is well adapted to the technical parameters of the computer. However, demands for computing capacity grew steadily, and in view of the impossibility of purchasing a medium computer it was necessary to modernize the GIER-4 gradually and this was eminently successful thanks to the well-conceived projects of a team of technicians, mechanics, and employees of UJV. In spite of the three-shift utilisation of this computer it has still not been possible to solve all of the assigned projects, and particularly those requiring high operational speeds, large internal memory capacity and high capacity external memory: therefore it was decided to purchase computer system of the JSEP series--the currently most advanced model -- the EC 1040 from the Robotron combine of the GDR. This computer was made operational in 1977, and its parameters make it an important assistant of the institute in the resolution of its demanding tasks: an operational speed of 380,000 operations per second, a 1,024 K-byte internal memory, 8 disc memories of 7.25 megabytes each, 6 magnetic tape units, and much additional peripheral equipment fill out this advanced system. For a further increase in the quality of the functioning of the computer center, 85 modernization tasks are planned for 1981 on the EC 1040 system, in addition to the construction of a terminal network extensive in terms both of the selection and preprocessing of data (for administrative purposes), and for the remote processing of data and the remote debugging and verification of newly developed programs (primarily for the scientific departments of the institute). Control computers linked up to research and development work in the field of reactor physics and technology are direct components of the experimental base (these are a Hewlett Packard 9600 E, HP 21 MX, CIS 3000, JPR 12, SMEP, and others).

The cited realities, and a number of others, were communicated to Prague journalists at a press conference in the UJV building in Rez, near Prague, a few days prior to the 25th anniversary of the institute by its new director, Engr Vasil Krett, candidate of sciences, the technical deputy, Engr Frantisek Kasak, and other personnel. A similar event took place several days prior to the ceremonial gathering of the whole UJV collective, which the president of the republic decorated "For Outstanding Work" for its role in fulfilling the demanding objectives of the Czechoslovak nuclear program.

Nuclear Research Institute panorama

Nuclear Research Institute workers

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TRANSITION FROM ANALOG TO DIGITAL TELEPHONE NETWORK--TECHNOLOGICAL REMARKS CONCERNING THE PROBLEM

Budapest HIRADASTECHNIKA in Hungarian Vol 31 No 10, 1980 pp 361-366

KLEINAU, Karl-Heinz, professor, Dr, Transportation College, Dresden

[Abstract] The major factors affecting the development of telephone systems--rapid advancement of LSI and VLSI technology in circuits and microprocessors specified by the customers, increased effectiveness of electronic data processing resulting from advancements in modular software and supporting software, and rapid advancement of light-conduction technology--are reviewed. Growth statistics indicate that specialized telephone-only (excluding telegraph and telex) systems will be required, and that they will have to be of the digital type to handle the expected volume. However, at the present time, full digitalization of a telephone network cannot be readily accomplished, especially not on the local branch network level. Special problems are created by the fact that voltage-level differences cannot be easily bridged, so that many subscriber devices would have to be replaced or considerably modified. Development is thus concentrated on batteries, overvoltage protection, ringing, signaling, coding, and hybrid functions. Much remains also be done in the area of reliability and availability. Advancements in light-conduction technology indicate that major applications may be expected during the 1980's. The advantages of this technology are well known; they are both technological and economic. However, full conversion to light-conductor technology is farther in the future because of the investment costs involved and also because the vastly increased capacity resulting from pulse-code modulation could not be fully utilized for some time to come. Figures 9; references 17: 6 Western and 11 German.

2542
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CATALOG OF 1979 COMPUTER PROGRAMS

Budapest HIRADASTECHNIKA in Hungarian Vol 31 No 9, 1980 pp 327-331

[Article by Dr Karoly GEHER, Institute of Communication Electronics, BME (Budapest Technical University)]

[Text] The summary presented below is a catalog of the computer programs prepared in 1979 for electronics. The program data were submitted by the leaders of the institutions involved upon request from the Institute of Communication Electronics, BME.

Following the established custom, we compiled programs concerning electronic devices, electronic circuits, communications equipment, and communication systems. The program catalog lists the programs in the order they were received.

The "Catalog of 1980 Computer Programs" will include those programs which are received by the Institute of Communication Electronics, BME (address: 1111 Budapest, Stoczek u. 2), by 31 January 1981.

Name of the program: ZEKE
Description: Testing by simulation of a system consisting of N servicers, a separate line of k(=0,...,K) length before them and a joint queue of m(=1,...,M) . Uses a Poisson input process, various service times, and smoothed sequencing.
Programming language: CDC 3300, SIMULA
Programmer: Mrs Ferenc Szentirmai, BHG FI [Beloiannisz Communications-Technological Factory, Development Institute]
Expert and the owning institution: BHG FI, Dr Geza Gosztony
Reference: Internal Technical Report 90110-234

Name of the program: POAS
Description: Modified version of the ZEKE program, with random sequencing.
Programming language: CDC 3300, SIMULA
Programmer: Mrs Ferenc Szentirmai, BHG FI
Expert and the owning institution: BHG FI, Dr Geza Gosztony
Reference: Internal Technical Report 99110-234

Name of the program: CREK
Description: Simulation of a M(M)n type mass service system with limited accessibility and loss, featuring the following service principle: up to k (k<n) servicing units are examined in cyclical sequence by the new demand; if no free one is found, it is lost.
Programming language: CDC 3300, SIMULA
Programmers: Gyula Csaszar and J. Attila Schuller
Expert and owning institution: BHG FI, Dr Geza Gosztony
Reference: Internal Technical Report 99110-84

Name of the program: GRAFILT
Description: Program packet for the designing and analysis of electrical circuits—primarily filters— for the GD80 GC graphic configuration. The novel feature of the programs is the utilization of interactive graphics for data entry and result display.
Programming language: GESAL
Programmers: Gabor Pronay and Tibor Thron and Laszlo Gefferth, BME HEI [Budapest Technical University, Institute of Communication Electronics]; Vilmos Kovacs and Tibor Tolnay-Knefely, MTA SZTAKI [Hungarian Academy of Sciences, Research Institute of Computer Technology and Automation]
Owning institution: MTA SZTAKI
Reference: GRAFILT user bulletins

Name of the program: RELDIS
Description: Examination of lifetime distribution on the basis of experimental data in the case where every test sample has developed fault.
Programming language: R 12, FORTRAN IV
Programmer: Gabriella Sugar, MIKI [Research Institute of the Instrument Industry]
Expert and owning institution: MIKI, Gabriella Sugar
Reference: "Statistical Analysis of Reliability Test Results of Electromechanical Components" by Gabriella Sugar and Denes Kauser; Relectronic '77 Conference publication, pp 597-605

Name of the program: Z 80 simulator
Description: Program system simulating the operation of the Z 80 microprocessor, suitable for monitoring assembler-level programs.
Programming language: R 10 PLM
Programmer: Tibor Ormosi, MIKI
Expert and owning institution: Tibor Ormosi, MIKI
Reference: Application manual

Name of the program: Z 80 cross assembler
Description: Compiler suitable for the modification of programs written in the assembler language of the Z 80 microprocessor.
Programming language: R 10 PLM
Programmer: Tibor Ormosi, MIKI
Expert and owning institution: Tibor Ormosi, MIKI
Reference: Application manual

Name of the program: SFQ
Description: From the measured values of the input signals of linear systems, determines the optimum parameters of the selected transfer weight function. Minimizes the square sum of the deviations of the measured and computed output values.
Programming language: FORTRAN IV, R 12
Programmer: Gabriella Sugar, MIKI
Expert and owning institution: MIKI, Dr. Tibor Soos
Reference: SFQ application description, 1980

Name of the program: INTEL 4040 simulator
Description: Program system simulating the operation of the INTEL 4040 microprocessor, suitable for monitoring the assembler-level programs.
Programming language: R 12 assembly
Programmer: Dr Tibor Soos, MIKI
Expert and owning institution: MIKI, Dr. Tibor Soos
Reference: Application manual

Name of the program: INTEL 4040 cross assembler
Description: Compiler, suitable for the modification of programs written in the INTEL 4040 microprocessor assembly language.
Programming language: R 12 assembly
Programmer: Dr Tibor Soos, MIKI
Expert and owning institution: MIKI, Dr Tibor Soos
Reference: Application manual

Name of the program: DDIG-1, digital filter transfer designing program
Description: P, T1, T2, C approximations, LP, HP, BP, BS domain.
Programming language: R 12 FORTRAN
Programmer: Dr Miklos Herendi, MIKI
Expert and owning institution: MIKI, Dr Miklos Herendi
Reference: Research report, December 1979

Name of the program: Graphic extension of AMPER-77 compiler
Description: Prepared for the programming of EMG-666, with added NE-2000 plotter. Commands: LLEFT, URITE, SFACT, WHERE, LOCATE, FACT, PLOTL, MARKER, NUMB, SYMB, LINES, AXIS.
Programming language: EMG-666 machine code
Programmer: Tibor Sziladi, MIKI
Expert and owning institution: MIKI, Tibor Sziladi
Reference: AMPER-77 manual

Name of the program: System to design active RC filters with DARC biquadratic resolution
Description: Supplement for designing basic subassemblies containing thin-layer resistors and chip capacitors.
Programming language: R 12 FORTRAN
Programmer: Dr Miklos Herendi, MIKI
Expert and owning institution: MIKI, Dr Miklos Herendi
Reference: Research report, December 1979

Name of the program: Debugger auxiliary program for programs written in the AMPER-77 measuring language
Description: Services: checking variables, their mofidication, line-by-line program execution, jump to any desired location, placement of STOP's, modification of the parameters of measuring automata during operation.
Programming language: EMG-666 machine code
Programmer: Tibor Veres, MIKI
Expert and owning institution: MIKI, Tibor Veres
Reference: AMPER-77 manual

Name of the program: MONITR
Description: Monitor module of the IPS-200 program system providing the control of the ICOMAT-200 LSI measuring system, which ensures the connection between the user's measuring program and the measuring system and enables the execution of the operator commands.
Programming language: MACRO
Programmer: Computer Technology Department, HIKI [Research Institute of the Communications Industry]
Expert and owning institution: HIKI, Peter Rozsa
Reference: User documentation of the IPS-200 programming language

Name of the program: EDI 200
Description: High-level, measurement-oriented translator program of the IPS-200 program system, which ensures the control of the ICOMAT-200 LSI measuring system.
Programming language: MACRO
Programmer: Computer Technology Department, HIKI
Expert and owning institution: HIKI, Peter Rozsa
Reference: User documentation of the IPS-200 programming language

Name of the program: IPS-11
Description: Program system ensuring the control of the ICOMAT-200 LSI measuring system; may be used as an autonomous program. Measuring programs may be designed and run, and the hardware of the measuring system may be tested with its aid.
Programming language: MACRO
Programmers: Peter Rozsa and Adorjan Szeles
Experts and owning institution: HIKI, Peter Rozsa and Adorjan Szeles
Reference: IPS-11 user documentation

Name of the program: IECSYS
Description: Ensures the handling of DEC-compatible interfaces under the RT-11 operating system in accordance with IEEE-488-1975 recommendation prepared for PDP-11 and TDA 1140 computers.
Programming language: MACRO
Programmer: Adorjan Szeles
Expert and owning institution: HIKI, Adorjan Szeles
Reference: IECSYS documentation

Name of the program: WRAP11
Description: Prepares the following for wire-wrapped units on the basis of the source list: wiring instructions with wire-length calculation and summation; connection list of the unit; input punched tape for a connection-checking device; check list.
Programming language: MACRO FORTRAN
Programmer: Istvan Kollar, HIKI
Expert and owning institution: HIKI, Istvan Kollar
Reference: WRAP11 user's manual, WRAP11 user description

Name of the program: ODTRT
Description: Debugging of MACRO programs written for PDP-11 computers.
Programming language: MACRO-11
Programmer: Adorjan Szeles, HIKI
Expert and owning institution: HIKI, Adorjan Szeles
Reference: User's manual

Name of the program: HK-LYUKSZA02P
Description: The program processes the integrated-circuit parameters recorded on punched tape, as measured by the ICOMAT 2 KF measuring automaton.
Programming language: FORTRAN IV or punched-card reader
Programmer: Agnes Rajk, HIKI
Expert and owning institution: HIKI, Agnes Rajk
Reference: -

Name of the program: ROMOS
Description: Function of the program: generation of the program masks of mask-programmed ROM circuits; testing of ROM and EAPROM circuits. The program prepares control tape for ICOMAT-2 and ICOMAT-110 measuring automata.
Programming language: FORTRAN IV and ASSEMBLER (ICL)
Programmer: Gabor Farkas, HIKI
Expert and owning institution: HIKI, Gabor FARKAS
Reference: User documentation for ordering TMS 8302 circuits

Name of the program: MAPHLA-1
Description: Used (1) to prepare simple integrated-circuit masks and (2) to generate mask-readable characters and texts (Mask and Photoplate Labeler)
Programming language: FORTRAN IV, ASSEMBLER (PDP-11)
Programmer: Gabor Farkas, HIKI
Expert and owning institution: HIKI, Gabor Farkas
Reference: -

Name of the program: TERMANAL
Description: Graphic-interactive program for calculating the stationary and temporally variable heat distribution of integrated circuit boards.
Programming language: SLANG-3
Programmers: Dr Vladimir Szekely, Pal Baji, and Marta Rencz (Mrs Kerecsen), Department of Electronic Devices, BME [Budapest Technical University]
Experts and owning institution: REMIX Radio-Engineering Enterprise, Dr Vladimir Szekely and Bela Szakacs

Name of the program: REZIDENS EDITOR
Description: Text editor for microcomputer containing the microprocessor 8080, capable of being placed in any memory-address domain of a two-kbyte ROM.
Programming language: 8080 ASSEMBLER
Programmers: Dr Kalman Tarnay, Dr Ferenc Massi, and Zsolt Koros, Department

of Electronic Devices, BME
Expert and owning institution: SZKI [Computer-Technology Coordination Institute]
Reference: Description of REZIDENS EDITOR for users

Name of the program: GRAFI
Description: Programming-language and processing program for drawing machines for describing any drawing for computer processing. It can be used for the preparation of the graphic documentation of manually or computer-designed printed-circuit cards.
Programming language: Columbus Fortran, Columbus Assembler
Programmers: Janos Cserno, Mrs Tibor Varadi, Gyula Vass, Arpad Vincze, SZKI
Expert and owning institution: Design-Automation Laboratory, SZKI, Janos Cserno
Reference: "GRAFI Programrendszer. Programozasi Kezikonyv" [GRAFI Program System. Programming Manual], available at SZKI, TAL [Design-Automation Laboratory]

Name of the program: Dimensioning of premagnetized coils
Description: The program dimensions premagnetized coils on ferrite or E core, or M and TM core, or M33 ferrite or other material.
Programming language: EMG-666 autocode
Programmers: Peter Pfliegel and Dr Janos Granat, BME-HEI
Expert and owning institution: BME-HEI, Dr Janos Granat and Peter Pfliegel
Reference: "Dimensioning of Premagnetized Coils With the EMG-666 Benchtop calculator"; scheduled for publication in HIRADASTECHNIKA

Name of the program: ISOA2
Description: Manufacture-simulation, statistical control, and expected wastage percentage of LC filters. Capable of being re-run from magnetic tape and multiple statistics preparation.
Programming language: ICL 4-70
Programmers: Gabor Enekes, Dr Jozsef Gaal, Dr Laszlo Gefferth, Dr Edit Halasz, Dr Gyorgy Pongor, and Dr Tibor Tron, BME-HEI
Expert and owning institution: TELEFONGYAR [Telephone Factory], Jeno Radvany, Laszlo Szente
Reference: Operating instructions, 1979

Name of the program: OPAL
Description: Optimum distribution of the investment fund destined for improving the traffic volume of hierarchic telecommunication networks on the basis of statistical network model.

Programming language: OS/8 BASIC, PDP 8e
Programmer: Gyula Sallai, PKI [Experimental Institute of the Postal Service]
Expert and owning institution: PKI, Gyula Sallai
Reference: PROCEEDINGS OF THE 9TH ITC No 628, 1979

Name of the program: ARDIS
Description: Cost optimization of telecommunication networks (number of levels, number of exchanges per level) on the basis of the statistical network model.
Programming language: OS/8 BASIC, PDP 8e
Programmer: Zoltan Papp, PKI
Experts and owning institution: PKI, Gyula Sallai and Zoltan Papp
Reference: "Cost Analysis and Optimization of Hierarchic Network Configurations" PKI Report, 1980

Name of the program: NESTRA'79
Description: Economic and technical assessment of possible traffic-control structures of the two upper levels of telecommunication networks, including the optimum traffic designing of the circuit clusters, in alternative or direct-path systems.
Programming language: OS/8 BASIC, PDP 8e
Programmer: Zoltan Dely, PKI
Experts and owning institution: PKI, Zoltan Dely and Gyula Sallai
Reference: "Traffic-Control System and Structure Designing" 1980

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MULTICOMPONENT DIGITAL FORCE, TORQUE METER FOR INTELLIGENT ROBOTS

Budapest FINOMMECHANIKA MIKROTECHNIKA in Hungarian Vol 19 No 10, Oct 80 pp 289-295

[Article by Karoly Fock, associate professor, Department of Process Control, BME (Budapest Technical University); Gyula Laczhazi, Dr, associate professor, Department of Electronics, BME; Gyorgy Antos, Dr, associate professor, Department of Process Control, BME; and Ferenc Zilahy, staff scientist, MTA-SZTAKI (Hungarian Academy of Sciences, Research Institute for Computer Technology and Automation). The authors have reported on an intermediate stage of this project at the IInd Industrial Robots Conference, held 26-28 June 1979 in Szeged]

[Text] The article describes in detail the major steps that have led to the design and construction of the force meter needed for the "wrist" of the arm of intelligent robots, consisting of six components. The study also considered "crosstalk." It details, at the block-diagram level, the electronic measuring circuit associated with the force meter, the individual steps of the analog and digital signal processing, and the function of the device generating a digital electrical signal in proportion to the force and torque components with a computer operating in the on-line mode.

Introduction

Industrial robot research today often involves the creation of systems capable of performing relatively complex tasks (such as assembly operations). Important facets of these studies, which involve considerable effort, are shape recognition and investigations aimed at measuring external forces bearing on the gripping organs of the robot, as well as sensing proximity.

In the course of these studies, major advancements were also achieved in the field of measuring multicomponent forces [1,2,3]. Multicomponent force transducers are often installed between the gripper and the arm (meaning into the wrist). The arm generates an electrical signal that is in proportion to the force and torque vectors bearing on the gripper in all spatial positions . This means that information becomes avaiable on the environment, the workpiece, and the parameters (such as the bolt-tightening torque) concerned.

Description of the Problem

In the course of joint studies carried out by MTA-SZTAKI and the Department of Process Control of the BME in the field of industrial robots, the need has developed to install a force and torque sensor into the wrist of a computer-controlled COROHAND type industrial robot (Fig. 1).

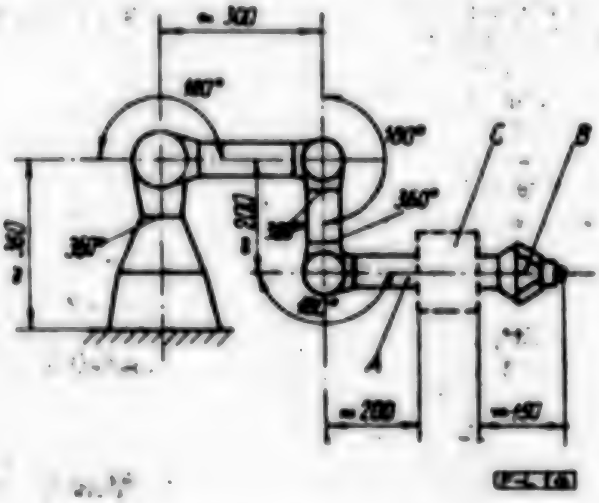


Fig. 1. a) Structural diagram of the COROHAND
b) COROHAND robot arm [photograph not reproduced]

Considering the functions of the robot and the development trends, we decided to develop a so-called six-component force meter [1,2].

Definition of the Task

The metrological task is to measure multicomponent force and to process the signals. The components F_x, F_y, F_z, M_x, M_y, M_z of the spatial F force and M torque vector (Fig. 2) bearing at the given point B must be determined simultaneously in the spatial coordinate system shown, and the electrical signals proportional to them must be made suitable for controlling the robot.

Starting Conditions

In view of the configuration of the gripper and the assembly tasks involved, the starting conditions for designing the force meter were the following:

- primary force (F) = 20 N
- primary torque (M) = 2 Nm, and
- h = 180 mm

(see Fig. 2).

In view of the complexity of the task, we decided that the permissible errors of the measurement may be higher than the errors customarily allowed in industrial force measurement [4], meaning that they may be in the order of magnitude of a few percents.

The relatively large displacement of Point B, meaning the value of the spring constant of the entire system being higher than customary in classical force measurement, is not necessarily detrimental since the relatively softer spring constant protects the transducer from major impacts when it collides with a foreign object.

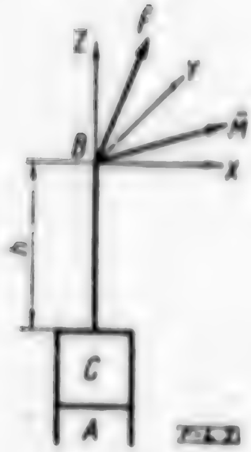
Since we lack applicable experience, we had difficulties in estimating the mutual effects of the individual components; however, we made it our goal to keep the effects at a low level.

It was also an understandable desire that the sensing should be independent of the moving speed and spatial location of the arm, insofar as the individual components are concerned; however, because of the lack of experience, we regarded this merely as a factor to be taken into consideration [6].

Designing a Six-Component Force Meter

Theoretical Fundamentals

The principle of the measurement of multicomponent force—irrespective of the design of the signal transducer—is the following: Let us assume that we desire to measure the effect of the force and torque vector in n different points and directions.



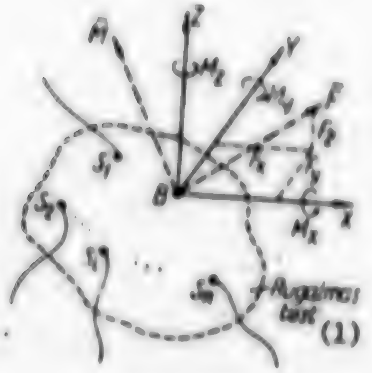


Fig. 2. Principle of the installation of the force meter
A - Robot arm
B - Gripping point
C - Transducer $|\overline{F}_{max}| = 20$ N; $|\overline{M}_{max}| = 2$ Nm; h = 0.18 m

Fig. 3. Measurement of multicomponent force
Key: 1 - Elastic body

An electrical signal S_i is generated in the individual points in proportion to the deformation caused (Fig. 3). Assuming elastic deformations, we find that the effects of the individual components are superimposed in these points, meaning that the relationship between the components and the electrical signals can be described by a linear equation system, so that the following applies:

$$\begin{vmatrix} S_1 \\ S_2 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ S_n \end{vmatrix} = \begin{Vmatrix} a_{11} & \cdots & a_{16} \\ a_{21} & \cdots & a_{26} \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ a_{n1} & \cdots & a_{n6} \end{Vmatrix} x \begin{vmatrix} F_x \\ F_y \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ M_z \end{vmatrix}; \qquad (1)$$

In view of the fact that the number of unknowns to be determined (F_x, F_y, F_z, M_x, M_y, M_z) is six, we need at least six signal-converting units ($n \geq 6$). The system of coefficients of the linear equation system describing the relationships among the measured signals and the components to be measured is called a coupling matrix in the literature. The coefficients of the coupling matrix express the effects of the individual components on the individual signal converters. In principle, each of the six components may affect each of the individual signal converters. In the ideal case, one coefficient is other than zero in each line of the coupling matrix.

To define the system of equations in a unambiguous manner, we must introduce the forces and torques bearing on the n selected points in a defined manner, and we must design the force-torque transducers in a proper mechanical manner. Modifying the earlier illustration (Fig. 4), we have in fact already sketched out the principle of the construction by realizing the transfer of force with the aid of the articulated bars marked E_i (decoupling bars). As the illustration shows, the individual sensors S_i obtain only force effects in the bar direction E_i since the bars are connected to the sensors in an articulated way, meaning to the part of the force/torque meter connected to the gripper. The sensors are fastened to a part connected to the robot arm.

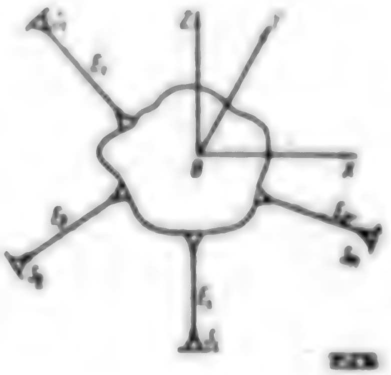


Fig. 4. Introduction of force and torque factors to the signal converters

Making the sensors, decoupling bars, and perhaps also the connecting parts of the same material is desirable from a metrological point of view (reduction of zero-point shifting); however, it is less so from the fabrication point of view [9].

In extension gauge resistor technology, it is customary to place the sensors on supports stressed to bending when measuring small force effects [6, 9].

Selection of the Design

To minimize the costs, we wanted to use the smallest possible number of sensors; thus, we rejected approaches involving the use of more than six sensors [1, 2, 3] right from the beginning.

Because of the fact that the force and torque vectors are very low in their nominal values, we felt that the introduction (transfer) of the force could be accomplished with thin cylindrical rods.

Reference [9] describes the approaches involving the use of decoupling bars (the possible layout of bars). The advantage of the approach illustrated in Fig. 5 is that the number of non-zero coefficients in the coupling matrix is relatively small [15] while the mechanical construction is relatively simple. (The illustration also shows some dimensions of which the importance will become evident later.) Decouplig bars are attached at defined points to the frame structure—which may be regarded as rigid—and these bars are connecting the frame structure to six spring-loaded measuring bodies equipped with elongation transducers. The frame is connected to the gripper of the robot (Point B), and the springs are connected to the robot arm (clamping of the console springs). The following is the system of equations describing the relationship between the forces bearing on the measuring bodies and the components $\overline{F}$, $\overline{M}$ (force-torque) — assuming that the measuring bodies obtain only bar-direction forces:

$$\begin{vmatrix} F_1 \\ F_2 \\ F_3 \\ F_4 \\ F_5 \\ F_6 \end{vmatrix} = \begin{Vmatrix} \frac{a+h}{2a} & 0 & 0 & 0 & \frac{1}{2a} & -\frac{1}{c} \\ \frac{a+h}{2a} & 0 & 0 & 0 & \frac{1}{2a} & \frac{1}{c} \\ \frac{h}{a} & 0 & 0 & 0 & \frac{1}{a} & 0 \\ 0 & -1 & 0 & 0 & 0 & 0 \\ 0 & \frac{h}{b} & -\frac{1}{2} & -\frac{1}{b} & 0 & 0 \\ 0 & -\frac{h}{b} & -\frac{1}{2} & \frac{1}{b} & 0 & 0 \end{Vmatrix} \times \begin{vmatrix} F_x \\ F_y \\ F_z \\ M_x \\ M_y \\ M_z \end{vmatrix} \qquad (2)$$

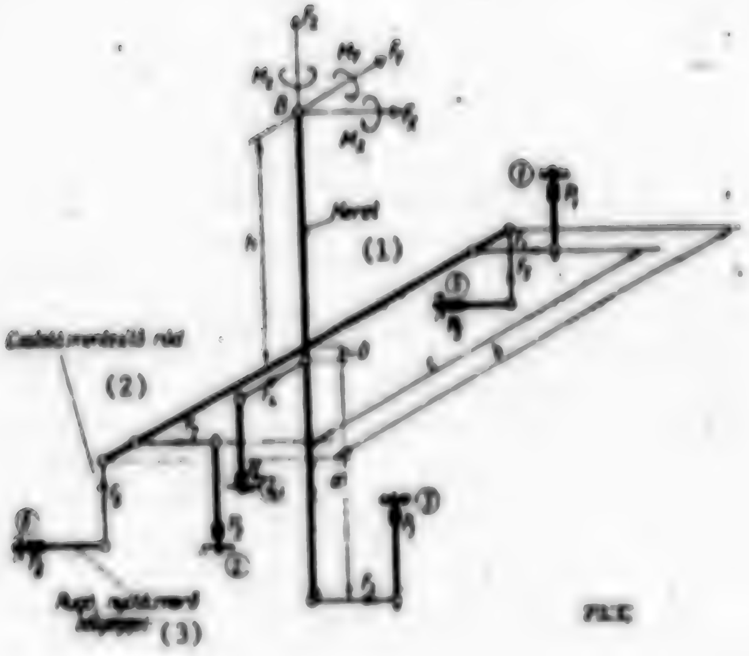


Fig. 5. Mechanical principle of the operation of the measuring head

Key: 1 - Frame
2 - Decoupling bar
3 - Spring with elongation transducer

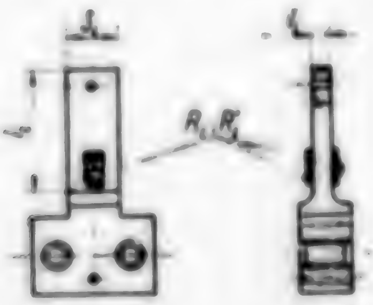


Fig. 6. a) Sketch of the measuring bodies 1, 2, and 3
b) Measuring body installed in place
[photograph not reproduced]

Description of the Six-Component Force Meter Completed

Mechanical Construction

The connecting parts were made of aluminum. Insofar as the geometric dimensions are concerned, a = 40 mm, b = 90 mm, and c = 80 mm have determined the principal dimensions of the converter.

The measuring bodies stressed for bending were made of high-grade alloyed steel. The heat treatment and aging were carried out with great care. The measuring bodies with constant cross section and clamped at one end were joined with bolts; wherever this was feasible, we made them of one piece (Elements 4, 5, and 6).

We allowed a bending stress of up to 200 N/mm^2 in the individual measuring elements, and we allowed a downward bend of 0.1 mm for the measuring elements. (The latter value represents a compromise between sensitivity and spring constant.) The individual converters were designed for a sensitivity of 1 mV/V.

The size of the elongation transducer (4 mm by 7.5 mm) predetermined the minimum width and length of the measuring bodies.

Our goal was to design measuring bodies which are easy to manufacture; thus, we designed Elements 1, 2, and 3 as shown in Fig. 6, and the combined Element 4, 5, and 6 as shown in Fig. 7. (The illustrations also show the elongation transducer resistors and the photographs of the measuring elements also show the decoupling bars.)

The following are the maximum forces bearing on the measuring elements:

$F_1 = F_2 = 105$ N

$F_3 = 140$ N

$F_4 = 20$ N

$F_5 = F_6 = 722$ N

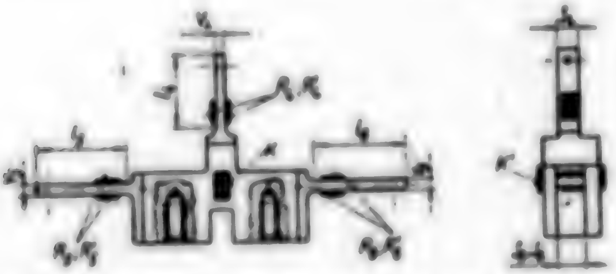


Fig. 7. a) Sketch of the measuring body 4, 5, and 6
b) Measuring body installed in place
[photograph not reproduced]

Table 1 shows the dimensions of the measuring bodies.

The decoupling bars were made of spring steel; both their ends were secured by electron-beam welding. An exception from this is Decoupling Bar 4, of which one end was attached to the measuring element with adhesive to facilitate assembly.

The decoupling bars were dimensioned according to the principle described in Reference [9]:

- we selected five-fold safety reserve, while using the thinnest possible bars of adequate strength, which did not buckle under compression;

- We exercised care to ensure that the force required to bend the decoupling bars when the measuring element deflects does not exceed one percent of the spring force of the measuring element.

Table 1. Geometric dimensions of the measuring elements

Measuring element	Length h in mm	Thickness v_1 in mm	Width s_1 in mm
1, 2	20	2.50	9.75
3	20	2.50	13.00
4	15	1.40	4.40
5, 6	20	2.50	6.70

The photograph of the measuring head (Fig. 8) allows us to recognize the components described so far on the basis of the sketch and the measuring elements.

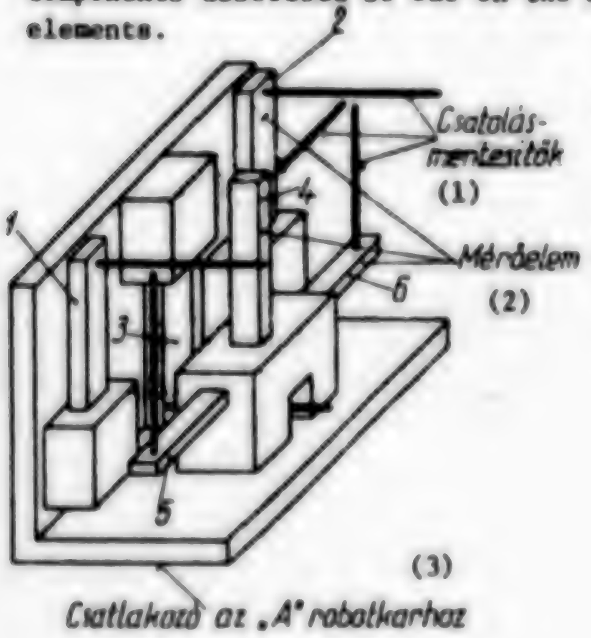


Fig. 8. a) Layout of the measuring elements of the force meter
b) The assembled force meter [photograph not reproduced]

Key: 1 - Decouplers
2 - Measuring element
3 - Connector to Robot Arm "A"

The following dimensions were obtained fot the decoupling rods (Table 2):

Table 2. Geometric dimensions of the decoupling bars

Decoupling bar	Length in mm	Diameter in mm
1, 2	30	1.5
3	30	1.5
4	30	1.0
5, 6	30	1.3

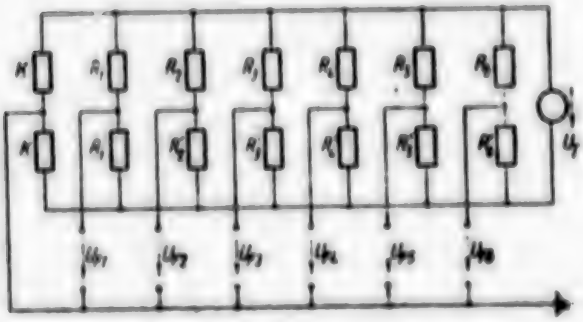


Fig. 9. Bridge circuit of the elongation transducer of the force and torque meter

Bridge Circuits With Elongation Transducer

We developed the full Wheatstone bridges (Fig. 9) with two active elongation transducers to reduce the temperature effects and to increase the sensitivity. We placed the "K" auxiliary measuring resistors on that part of one of the measuring bodies (Fig. 7) which practically does not deform.

Supply of the bridge comes from a highly stable U_T = 2.4 V, d.c., generator.

Evaluation of the Force-Measuring Head

We examined the force/torque meter in an experimental loading system. The apparatus permitted us to examine the effects of all three components of the force and the torque. We measured the output signals of all six transducers under all loading conditions.

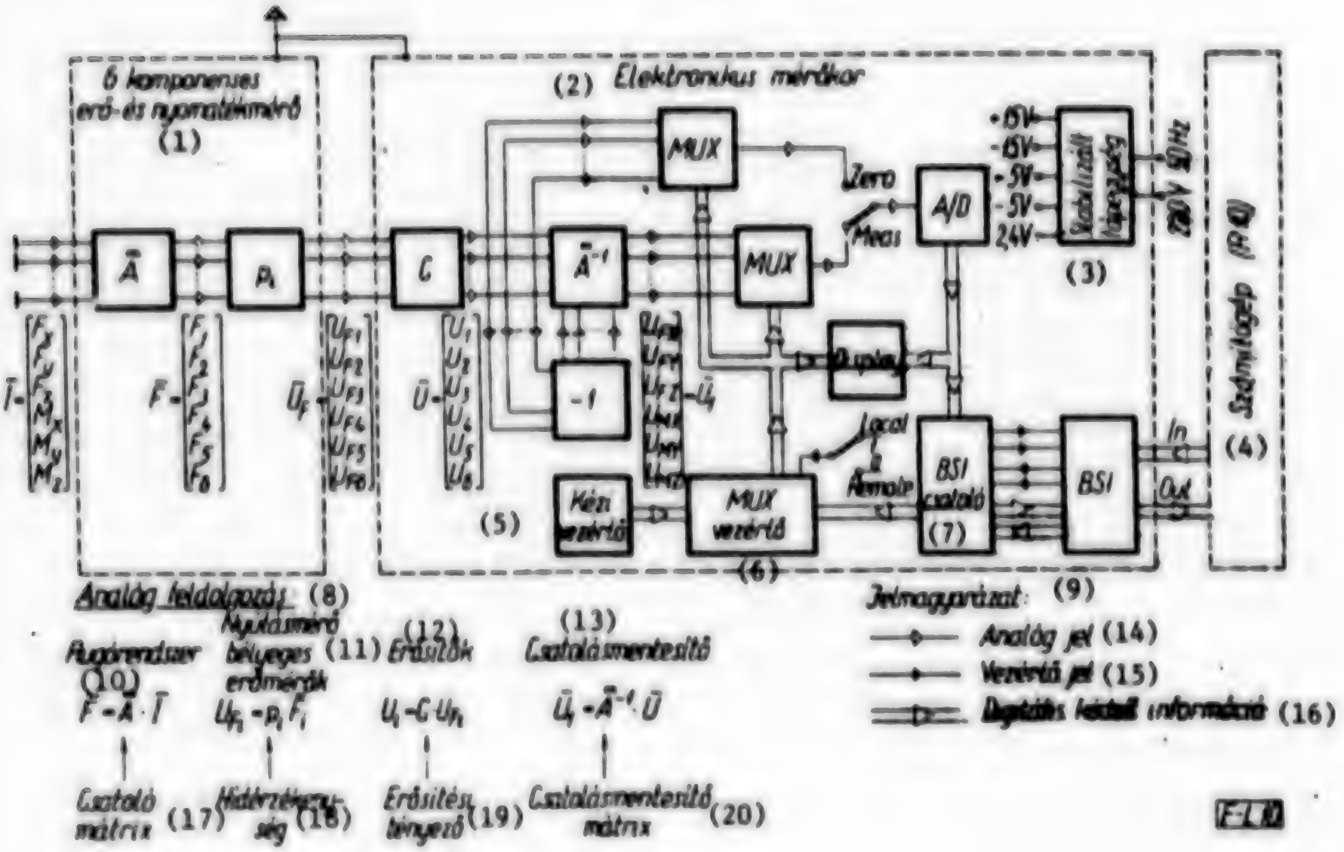

6 komponenses erő- és nyomatékmérő
(1)
(2) Elektronikus mérőkör
MUX
Zero
Meas
A/D
+15V
-15V
+5V
-5V
24V
Stabilizált tápegység
220V 50Hz
(3)
Számítógép (R10)
(4)
A
p_i
C
A^{-1}
-1
MUX
Display
Local
Remote
BSI csatoló
(7)
BSI
In
Out
Kézi vezérlő
(5)
MUX vezérlő
(6)
$\bar{T}=[F_x, F_y, F_z, M_x, M_y, M_z]$
$\bar{F}=[F_1, F_2, F_3, F_4, F_5, F_6]$
$\bar{U}_F=[U_{F1}, U_{F2}, U_{F3}, U_{F4}, U_{F5}, U_{F6}]$
$\bar{U}=[U_1, U_2, U_3, U_4, U_5, U_6]$
$\bar{U}_t=[U_{Fx}, U_{Fy}, U_{Fz}, U_{Mx}, U_{My}, U_{Mz}]$
Analóg feldolgozás (8)
Rugórendszer (10)
Nyúlásmérő bélyeges erőmérők (11)
(12) Erősítők
(13) Csatolásmentesítő
$\bar{F}=\bar{A}\cdot\bar{T}$
$U_{F_i}=p_i F_i$
$U_i=C\cdot U_{F_i}$
$\bar{U}_t=\bar{A}^{-1}\cdot\bar{U}$
Csatoló mátrix (17)
Hídérzékenység (18)
Erősítési tényező (19)
Csatolásmentesítő mátrix (20)
Jelmagyarázat: (9)
Analóg jel (14)
Vezérlő jel (15)
Digitális kódolt információ (16)
F-L10

Fig. 10. Block diagram of the six-component force and torque meter

Key: 1 - Six-component force and torque meter
2 - Electronic measuring circuit
3 - Stabilized power supply
4 - Computer (R 10)
5 - Manual control
6 - MUX control
7 - BSI connector

[Key continued on next translation page]

[Key for Fig. 10, continued from preceding page]

8 - Analog processing
9 - Explanation of symbols
10 - Spring system
11 - Force measuring units with elongation transducer
12 - Amplifiers
13 - Decoupler
14 - Analog signal
15 - Control signal
16 - Digital coded information
17 - Coupling matrix
18 - Bridge sensitivity
19 - Gain factor
20 - Decoupling matrix

The examination had two goals: first the better understanding of the principle of operation; second the trial of the construction approaches (such as the bolt-attachment of the measuring bodies) and the technological methods (such as heat treatment and aging). The selectivity of the measurement transducer is of vital importance for subsequent signal processing. We had to ascertain the degree to which the measurement transducer in fact follows the theoretical principle developed on the basis of simplifying assumptions (see Equation (2)). The problem was that there was no technological way during construction for the articulated clamping of the decoupling rods, so that crosstalk and nonlinearities had to be expected.

The invert version of the coupling matrix, the so-called decoupling matrix, had to be realized for signal processing. The closer comes the behavior of the measurement transducer to the theoretically derivable system of equations, the simpler will be the design of the signal-processing circuit, and the simpler and the more accurate will be the realization of the invert matrix.

In numerical terms this means that we must find out the extent to which the zero elements are indeed zero in the coupling (or decoupling) matrix. An answer to this question can be obtained by examining the decoupling matrix.

Using the symbols shown in Fig. 5, we assume that the sensitivity of the individual force-measuring bridges with elongation transducer is

$$p_i = \frac{U_{Fi}}{F_i} \qquad (3)$$

Equation (4) defines the theoretical decoupling matrix, derivable from Equations (2) and (3):

$$\begin{vmatrix} F_x \\ F_y \\ F_z \\ M_x \\ M_y \\ M_z \end{vmatrix} = \begin{Vmatrix} \frac{1}{p_1} & \frac{1}{p_2} & -\frac{1}{p_3} & 0 & 0 & 0 \\ 0 & 0 & 0 & -\frac{1}{p_4} & 0 & 0 \\ 0 & 0 & 0 & 0 & -\frac{1}{p_5} & -\frac{1}{p_6} \\ 0 & 0 & 0 & -\frac{h}{p_4} & -\frac{b}{2p_5} & \frac{b}{2p_6} \\ -\frac{h}{p_1} & -\frac{h}{p_2} & \frac{h+a}{p_3} & 0 & 0 & 0 \\ -\frac{c}{2p_1} & \frac{c}{2p_2} & 0 & 0 & 0 & 0 \end{Vmatrix} \times \begin{vmatrix} U_{F1} \\ U_{F2} \\ U_{F3} \\ U_{F4} \\ U_{F5} \\ U_{F6} \end{vmatrix} \quad (4)$$

To make understanding easier, those values which differ from zero in the theoretical expression also are printed in italics.

The results showed, on the one hand, the extent to which we succeeded in making the identical measuring elements truly identical. In principle, the measuring bodies 1 and 2, and 5 and 6 are identical. The near identicalness of the absolute values, shown in italics, of the columns for 1 and 2, and 5 and 6 in the A^{-1} matrix confirms the identicalnesses within the manufacturing tolerance.

We can evaluate the magnitude of the undesirable crosstalk expressed as percent of the maximum absolute-value element in the individual rows of the $\tilde{A}^{-1}$ matrix. According to this, the maximum crosstalk in the first row, for example (during the determination of the value of F_x), is

$$\frac{a_{16}}{a_{13}} \cdot 100 = \text{approx. } 3\%$$

In a similar manner, we obtain the values of 34%, 10%, 4%, 2%, and 6% for the other rows, in this order. It is evident that the extent of undesirable crosstalk is significant particularly in the measurement of the F_y, F_z, and M_x components.

How are we to assess this phenomenon? Since the elements theoretically of the value zero of the decoupling matrix differ from zero significantly in some areas, we must consider these elements too in the realization of the measuring circuit. Accordingly, the decoupling matrix theoretically containing 14 elements that differ from zero has in fact more than 14 such elements. The question rightfully arises whether it has indeed made sense to settle on the layout illustrated in Fig. 5, and whether it should have been advisable to first make an easier-to-manufacture measuring head of several matrixes? An answer to this question can be given only if we have additional experimental information available. At the present time, all we can say is that consideration of the relatively high crosstalk weighs still little, thus generating smaller faults than a measuring head with a theoretically higher-weight factor.

The configuration of the decoupling matrix established on the basis of the measured data (dimensions: [F] = N; [M] = Nm; [U_P] = mV):

$$\bar{\bar{A}}^{-1} = \begin{Vmatrix} 0,4956 & 0,5192 & -0,6561 & 0,0066 & -0,0054 & -0.0181 \\ 0.0346 & 0,0304 & -0,0545 & -0,1586 & -0,0110 & 0,0020 \\ 0,0191 & 0,0369 & -0,0765 & -0,0242 & -0,3650 & -0,3519 \\ 0.1106 & -0,0673 & -0,1154 & -3,0444 & -2,0796 & 1,6061 \\ -9,1462 & -9,7775 & 15,7319 & 0,0806 & 0,3065 & 0,3131 \\ -2,1322 & 2,0747 & 0,1231 & -0,0214 & 0,1286 & 0,05818 \end{Vmatrix} \qquad (5)$$

Analog and Digital Signal Processing

The goal of the signal processing is the generation of electrical signals in proportion to the force and torque components to be measured, so that the signals are also suitable for processing in a computer operated in the on-line mode.

Figure 10 illustrates the block diagram and the most important signals of the force-measuring device developed in the course of our project.

The most important steps of analog signal processing are the amplification of the low-level $\bar{U}_P$ signals originating from the measuring bridges and the realization of the decoupling by electronic means. The low-noise, low-drift amplifiers, marked "C," include the organs for accomplishing the required zero-point shifting (taring). The adequately high signal level of the channel amplifiers makes the use of special analog integrated circuits in the decoupling computer unit unnecessary. The computer unit contains totalizer circuits with up to six inputs, of which the input weight factors can be set to the corresponding values of the decoupling matrix (Equation (5)) described earlier. In order to have the totalization right in terms of sign, we also need the derivation of the inverted values of the output voltages $\overline{U}$ of the amplifiers. The "-1" unit, containing six unity-gain inverters, performs this task.

The voltages $\overline{U}_1$, proportional to the force and torque components to be measured, are measured digitally with the measuring instrument set to MEAS, with the aid of the measuring-point selector (MUX) and the analog-to-digital converter.

In the LOCAL mode of operation, the measuring-point selector can be stepped manually via the MUX VEZERLO [MUX CONTROLLER] unit. In the REMOTE mode of operation, addressing via the computer through the BSI is possible. The analog-to-digital converter, Type AD 2010 E/R (Analog Devices), serially transmits the measured values to the computer in the two-byte BCD code via the BSI interface unit. The speed of the analog-to-digital converter is 24 conversions per second.

Zeroing of the measuring bridges is accomplished in the ZERO switch position, as is the taring in any position of the robot arm. The MUX VEZERLO simultaneously operates the two measuring-point selectors, and the position of the ZERO/MEAS switch determines whether measurement or zeroing (taring) is carried out.

The DISPLAY unit consists of the row of LED's indicating the selection of the components to be measured, and the 3-1/2 digit, seven-segment display built into the analog-to-digital converter.

The photograph of the measuring instrument is shown in Fig. 11.

Fig. 11. The electronic signal-processing unit of
the force and torque meter
[photograph not reproduced]

Experimental Results

Using the signal-processing device developed on the basis of the decoupling matrix (Equation (5)) established from measured data, we repeatedly examined the performance of the force meter on the test bench.

Of course, the realization of the elements of the matrix (5) can be at a finite accuracy only; furthermore, the electronic circuits have errors too, so that ultimately, it can be stated that, using the six-component force and torque meter,

- The linearity error of a single measurement of a force or torque component, relative to the theoretical straight line, is up to ±7% of the full deflection;

- the maximum crosstalk error (only in case of measurement of defined components: M_y when measuring F_x, M_x when measuring F_y, and M_y when measuring F_z): 10% relative to the nominal measurement range. The crosstalk is less than 5% for the other components;

- the shifting of the zero point is never more than ±2% even after repeated load cycles;

- there was no evidence of hysteresis.

Acknowledgment

The six-component digital-output force and torque meter realized as a result of the research/development project described in this article is due to the cooperative effort of a team. The authors thank Mrs Ferenc Juhasz, assistant staff scientist, for the preparation of the computer programs; Tibor Csubak, assistant staff scientist, and Laszlo Kuti, assistant professor, for making the digital signal-processing unit and the power-supply device.

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BRIEFS

LASER RESEARCH, UTILIZATION--Romania, one of the first countries in the world to construct lasers with its own resources (the helium-neon laser in 1963), has given and continues to give special attention to this new field of technology with more and more numerous applications in the most varied fields of contemporary life: in medicine, in the transmitting of information, in geodesy, in aviation, in telemetry, in construction work, in optics, etc--applications which envisage the use of the laser for peaceful purposes. The policy of the Romanian Communist Party assigns an important place to basic and applied scientific research. The implementation of this policy took concrete form with the establishment of the Institute for Physics and the Technology of Radiation Apparatuses (IFTAR) which, together with the research in the field of lasers and its application carried out in other institutions such as the Bucharest Polytechnical Institute and the Military Academy, continues the Romanian tradition in this important field of science and technology. [Excerpts] [Bucharest VIATA MILITARA in Romanian Nov 80 p 23]

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